UNIVERSITI PUTRA MALAYSIA

EFFECTS OF FOREST HARVESTING OPERATIONS ON SUSPENDED SEDIMENT AND SOLUTE LOADS IN THE SUNGAI WENG EXPERIMENTAL WATERSHEDS, KEDAH, PENINSULAR MALAYSIA

INTHAVY AKKHARATH.

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By

INTHAVY AKKHARATH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy.

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SPECIAL DEDICATION

TO MY BE LOVED WIFE, SISONGKHAM AND OUR CHILDREN KITTIPHANH, THANTHIVA AKKHARATH AND TO MY PARENTS, MR LEOKHAM AND MRS SOMSY AKKHARATH, WHO LAID MY ACADEMIC CAREER FOUNDATION AND TO ALL OF THE AKKHARATH FAMILY MEMBERS FOR THEIR CONSTANT MORAL SUPPORT AND INSPIRATIONS.

GOD BLESSES THEM ALL!

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

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Chairman: **Associate Professor Lai Food See, PhD**

Faculty: **Forestry**

This study examines the effects of logging operations on sediment and solute yields in four steep catchments referred to as the Sungai Weng Experimental Watersheds located in Ulu Muda Forest Reserves Kedah, Peninsular Malaysia. Watershed 1 (W1) is a control catchment where logging was not allowed throughout the period of study. Watershed 2 (W2) was logged based on stringent guidelines as recommended by the Forestry Department hitherto referred to as reduced impact logging (RIL). Watershed 3 (W3) was logged based on conventional logging (CL) practices. Watershed 5 (W5) is a bigger watershed, where the experimental basins are nested within and selected to examine the downstream and cumulative effects of logging operations including in those areas worked previously.

The general aim of this study was to compare the relative impacts of CL and RIL on sediment output. In this study, the extent of sediment source areas in W2 and W3 in the form of roads, skid trails and log landings and their implication on sediment output was also examined. In W2, the logging roads density was 30 m/ha, while the density of skid trail was 68 m/ha and the exposed area was 43 ha, about 5% of total watershed area. In W3, the logging road density was 47 m/ha and the density of skid trail was 101m/ha; exposed area was 59 ha, about 9% of watershed area.

The most reliable and suitable method was chosen to determine the sediment yield of the four catchments was estimated using data assembled for the rising and falling discharge stages. In W1, suspended sediment concentrations are high during storms even though under natural forests. The peak concentrations sampled were between 1,278 to 1,896 mg/l from 1997 to 2002 respectively. The annual sediment yields were 160, 199, 148, 97, 79, and 80 t/km^2/yr generated from 1997 to 2002 respectively.

During logging operations, in W2, the annual sediment yields significantly increased from 176 to 1,151 t/km^2/yr in year 2000 and 2002 respectively. In W3, the sediment yields increased dramatically to 2,133; 5,386; 4,501 t/km^2/yr over the period of 1998 to 2000 respectively. After logging ceased, sediment yield decreased to 869 and 684 t/km^2/yr from 2001 and 2002 respectively. Sediment yield in W5 was much less even though, the sediment yields from the experimental watersheds W3, in particular was high. Depositions of sediment along the stream channel leading to the gauging site of W5 and dilution from upstream channels were the main reason for the lower yield. Therefore, in W5 the sediment yield was contributing 143, 284, 829, 458, 178, and 163 t/km^2/yr, in over the six-year period from 1997 to 2002 respectively.

Stream water quality was measured in each study watershed and the results revealed that solute loads were much lower than sediment loads. In W1, the annual solute yields were 12.5, 13.5, 20.1, 14.8, 13.7, and 13.8 t/km^2/yr generated from 1997 to 2002 respectively. During logging operations, in W2, solute yields were 20.3, 13.4, 11.3 t/km^2/yr, for the year 2000, 2001 and 2002, respectively. In W3, solute out put was 30.8, 27.0 and 20.0 t/km^2/yr. However, the annual sediment yields appeared to have declined to 18.0 and 14.2 t/km^2/yr, in the following two years 2001 and 2002, respectively. In W5, solute out put was contributing 17.5, 16.8, 27.0, 25.4, 23.1 and 17.3 t/km^2/yr, in over the six-year period from 1997 to 2002.

The results of the study suggest that with proper control measures, the effects of logging on sediment loads in particular, can be substantially reduced. The increase of sediment yield in W2 to 1,151 t/km^2/yr in 2002 with 80% the study watershed was logged suggests that RIL exerted significant influence on sediment output. With respect to pre-logging or control conditions, the analyses suggest that conventional logging can results in over 40 times the sediment yield during the logging operations. The positive effects of RIL can be achieved through careful planning, scheduling and control of logging operations.

Abstrak tesis yang dikemukakan kepada Senat Univeristi Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

KESAN-KESAN OPERASI PENUAIAN HUTAN KE ATAS MENDAPAN MAMPAT DAN MUATAN BAHAN KIMIA DI KAWASAN KAJIAN TADAHAN AIR SUNGAI WENG, KEDAH, SEMENANJUNG MALAYSIA.

Oleh

INTHAVVY AKKHARATH

Ogos 2005

Pengerusi: **Profesor Madya Lai Food See, PhD**

Fakulti: **Perhutanan**

Kajian ini adalah untuk mengenalpasti kesan-kesan operasi pembalakan ke atas pemendapan mendapan di empat lokasi kawasan kajian tadahan air yang curam yang terletak di Hutan Simpan Ulu Muda, Kedah, Semenanjung Malaysia. Tadahan air 1 (W1) adalah sebagai tadahan air kawalan di mana pembalakan tidak dibenarkan sepanjang tempoh kajian. Tadahan air 2 (W2) adalah kawasan yang telah dibalak mengikut garispanduan yang ketat yang disyorkan oleh Jabatan Perhutanan iaitu mengurangkan kesan pembalakan (Reduced Impact Loging). Tadahan air 3 (W3) adalah kawasan dibalak berdasarkan kepada amalan pembalakan konvensional (Conventional logging). Tadahan air 5 (W5) adalah kawasan tadahan air yang besar, di mana lembah kajian yang dipilih dan diasingkan kepada beberapa bahagian untuk

mengkaji kesan-kesan hiliran dan kumulatif operasi pembalakan termasuk dalam kawasan yang telah dikerjakan sebelum ini.

Tujuan umum kajian ini adalah untuk membandingkan impak relatif (CL) dan (RIL) ke atas keluaran mendapan. Dalam kajian ini, perkembangan kawasan-kawasan sumber mendapan dalam W2 dan W3 dalam bentuk jalan utama, jalan penarik dan matau balak dan implikasinya keatas keluaran mendapan juga dikaji. Dalam W2, kepadatan jalan-jalan pembalakan adalah 30m/ha, manakala kepadatan jalan penarik adalah 68m/ha dan kawasan lapang terbuka adalah 43 ha, kira-kira 5% daripada keseluruhan kawasan tadahan. Dalam W3, kepadatan jalan pembalakan adalah 47m/ha dan kepadatan jalan penarik adalah 101m/ha, kawasan terdedah adalah 59 ha kira-kira 9% daripada kawasan tadahan.

Kaedah yang boleh dipercayai dan sesuai dipilih bagi menentukan hasil mendapan bagi keempat-empat tadahan air seterusnya dianggarkan dengan menggunakan data gabungan peringkat kenaikan dan kejatunan bahan buangan. Dalam W1, kepekatan mendapan adalah tinggi semasa ribut walaupun di hutan asli. Sampel yang mempunyai kepekatan puncak adalah 160, 199, 148, 97, 79 dan 80 t/km^2/yr didapati daripada 1997 hingga 2002.

Semasa operasi pembalakan, dalam W2 hasil mendapan tahunan meningkat dengan Sangay bererti dari 176 ke 1,151 80 t/km^2/tahun masing-masing pada tahun 2000 dan 2002. Dalam W3, hasil mendapan tahunan adalah meningkat secara mendadak ke 2,133; 5,386; 4,501 80 t/km^2/tahun iaitu masing-masing dalam jangka masa tahun 1998 dan 2000. Selepas pembalakan, hasil mendapan berkurangan dari 869 ke 684 80 t/km^2/yr iaitu pada tahun 2001 dan 2002. Hasil mandapan di W5 adalah berkurangan walaupun hasil mendapan di kawasan kajian tadahan di W3 adalah tinggi. Pembuangan mendapan di sepanjang laluan air mengakibatkan kawasan 'gauging' di W5 dan pelarutan mendapan dari kawasan tadahan air atas adalah alasan utama menyebabkan kesan mendapan yang rendah. Walaubagaimanapun, di W5 hasil mendapan menyumbang sebanyak 143, 284, 829, 458, 178 dan 163 80 t/km^2/yr dalam jangkamasa 6 tahun daripada tahun 1997 hingga 2002.

Keputusan kualiti air sungai diukur dalam setiap kajian tadahan air menunjukkan muatan bahan kimia adalah terlalu rendah daripada muatan mendapan. Di W1, penghasilan bahan kimia tahunan menyumbang kepada12.5, 13.5, 20.1, 14.8, 13.7 dan 13.8 t/km^2/tahun daripada tahun 1997 hingga 2002. Di W2, tiga tahun pertama sebelum operasi pembalakan, keluaran 'solute" adalah 18.6, 13.3, 28.5 t/km^2/tahun untuk tahun 2000, 2001 dan 2002. Di W3, keluaran 'solute' hádala 30.8, 27.0 dan 20.0 80 t/km^2/tahun pada dua tahun berikutnya pada tahun 2001 dan 2002. Di W5, keluaran 'solute' menyumbang kepada 17.5 16.8, 27.0, 25.4, 23.1 dan 17.3 80 t/km^2/tahun dalam tempoh enam tahun iaitu dari 1997 hingga 2002.

Keputusan kajian mengesyorkan bahawa perlunya kawalan yang sempurna terutamanya bagi mengurangkan kesan mendapan akibat aktiviti pembalakan. Pertambahan hasil mendapan di W2 sehingga 1,151 t/km^2/tahun dalam tahun 2002 dengan meliputi 80% kajian tadahan pembalakan menunjukkan RIL 'exerted' menyebabkan perbezaan yang bererti ke atas keluaran mendapan. Berdasarkan kepada keadaan sebelum pembalakan atau kawalan kajian, analisa mencadangkan pembalakan konvensional akan menghasilkan lebih 40 kali hasil mendapan semasa operasi pembalakan. Walaubagaimanapun, dalam peringkat yang tertentu, RIL boleh dicapai melalui perancangan yang berhati-hati, penjadualan dan kawalan operasi pembalakan.

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